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Kai Hielscher

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Department of Economics
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Diskussionspapier Nr. 113
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Monetary Policy Delegation and Transparency of Policy Targets: A Positive Analysis

KAI HIELSCHER

Zusammenfassung/ Abstract

We show that, in a two-stage model of monetary policy with stochastic policy targets and asymmetric information, the transparency regime chosen by the central bank does never coincide with the regime preferred by society. Independent of society's endogenous choice of delegation, the central bank reveals its inflation target and conceals its output target. In contrast, society would prefer either transparency or opacity of both targets. As a conclusion, the choice of the transparency regime should be part of the optimal delegation solution.

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1 Introduction

The recent past of monetary policy-making was characterized by increasingly independent central banks and a stronger focus on price stability in many countries. Theoretically, the benefits of such a development can be explained by the research on time-inconsistent policies (Kydland and Prescott, 1977; Barro and Gordon, 1983). In a seminal paper, Rogoff (1985) shows that a society's welfare can be increased through isolating monetary policy from political pressure (independence) and through appointing a central banker which is more inflation averse than society (conservatism).[1] Today, this combination of independence and conservatism (effective conservatism) is a prominent feature of monetary policy around the world. For example, Fry et al. (2000) show that, in 1998, 71% of central banks judge themselves as being independent.

In many countries, the institutional reforms have been accompanied by more transparency of monetary policy-making. Transparency is often seen as an important issue in achieving the necessary democratic accountability of independent and conservative central banks (Blinder et al., 2008; Dincer and Eichengreen, 2009). Consequently, research on central bank transparency has grown rapidly throughout the last decade. One major strand of the transparency literature addresses political transparency. Political transparency refers to the distribution of information between central banks and the private sector regarding policy goals, their priorities and quantification.[2] Up to now, the theoretical literature reached no consensus on the effects of political trans-

[1] There is also evidence challenging the desirability of such a delegation solution. For example, McCallum (1995) argues that the time-inconsistency problem persists because delegation arrangements might be changed ex post. Muscatelli (1998) shows that, in the case of uncertain preferences, delegation might not be beneficial. Demertzis et al. (2004) reveal a conflict between fiscal and monetary policy under delegation.

[2] Besides political transparency Geraats (2002) identifies four more categories: economic, procedural, policy and operational transparency. Hahn (2002) distinguishes between knowledge, operational and goal (political) transparency. See Geraats (2002), Blinder et. al. (2008) or van der Cruijsen and Eijffinger (2009) for a detailed survey of the related literature.

parency on macroeconomic performance and social welfare.[3]

Figure 1: Monetary policy structure

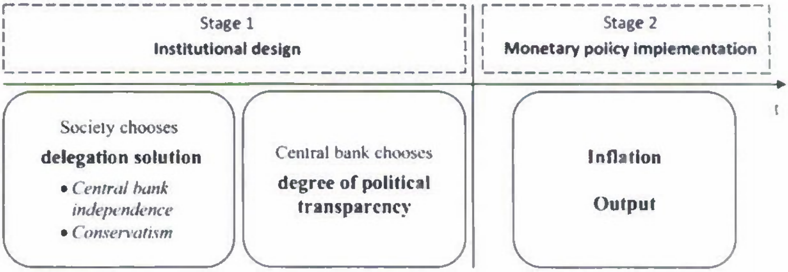


Figure 1 illustrates a stylized sequential structure of monetary policy. Monetary policy is subdivided in two stages. The first stage describes the entire determination of the institutional setting with the following sequential events. First, society decides on the terms of delegation; i.e., it chooses both the level of independence and the degree of conservatism of its central bank (effective conservatism). Second, the appointed central bank then sets the level of political transparency. In the second stage, monetary policy is conducted, with inflation and production being the macroeconomic policy outcome. While policy implementation in the second stage is a repeated event, the institutional setting in stage 1 represents a long-term decision.

This paper addresses two shortcomings of the existing theoretical literature on political transparency which can be explained on the basis of this simplistic structure of monetary policy-making. First, most contributions, that aim at answering the question whether political transparency is socially beneficial, have a purely normative perspective. Hence, different from the structure displayed in figure 1, this literature

[3] We review this literature briefly in section 2.

implicitly assumes that society itself is able to choose the level of central bank transparency. But, in reality, most central banks determine how transparent they are. As a consequence, a conflict may arise between the degrees of transparency chosen by the central bank and the socially optimal degrees of transparency. However, up to now, there is only little research with a positive perspective to address such a conflict.[4]

Second, in the literature on the optimal choice of transparency, the delegation solution is prevalently treated as exogenous. Given the sequence of events as illustrated in figure 1, society's choice on delegation and the central bank's choice on transparency are not independent of each other. Consequently, the endogenous choice of delegation should be considered when analyzing the benefits and the choice of transparency. There is a lot of research separately addressing the endogenous choice of delegation. However, to our knowledge, there is no research which considers the link between the endogenous choices of delegation and transparency.

This paper aims at filling the described gaps. Using a simple neoclassical time-inconsistency framework, monetary policy is modeled as a two-stage game between the private sector and the central bank as illustrated in figure 1. In the first stage, the institutional design is determined. Society first chooses the delegation solution and the appointed central bank then determines the transparency regime. In the second stage, monetary policy is conducted. We show that, in a model with stochastic policy targets and asymmetric information, the transparency regime chosen by the monetary authority, which the model predicts to be more inflation averse than society, does not coincide with the regime preferred by society. Independent of society's choice of delegation, the central bank decides to reveal the inflation target and to conceal the output target. However, society either prefers transparency or opacity of both targets.

Many central banks have often been accused of being too secretive (e.g. Svensson, 2002). Our results imply that central banks can also be excessively transparent.

[4]See section 2.

Furthermore, the model's predictions with respect to the publication of targets is in line with the observed behavior of many central banks. In practice, most central banks have transparent inflation targets but are very opaque with respect to other targets (Geraats, 2006).

The paper is organized as follows: Section 2 briefly reviews the related literature. Section 3 introduces the basic two-stage model of monetary policy. Section 4 analyzes the policy implementation process in stage 2 and derives equilibrium policy outcome. In section 5, the endogenous choice of delegation and transparency is examined. Section 6 discusses the results in detail. Section 7 concludes.

2 Brief review of literature

This theoretical paper contributes to the literature on political central bank transparency. We limit the following review to the theoretical research on the aspects of political transparency which this paper addresses. Excellent surveys of the entire transparency literature are provided by Hahn (2002), Geraats (2002), Blinder et al. (2008) or van der Cruijsen and Eijffinger (2009).

The theoretical literature on political transparency prevalently argues in favor of the hypothesis that transparency arrangements matter for a country's macroeconomic performance. However, the literature has not yet come to unambiguous conclusions with respect to the social desirability of transparency. In a seminal paper, Cukierman and Meltzer (1986) show that higher transparency, resulting from a higher quality of money control, lowers the inflation bias but restricts the policymaker's ability to boost output through surprise inflation. In a framework with endogenous wage setting by unions, Sørensen (1991) shows that uncertainty of the policy maker's preferences may be beneficial. Eijffinger et al. (2000a, 2003) find a detrimental effect of additive uncertainty of central banks' preferences on the inflation bias and on inflation vari-

ability but also identify a beneficial effect on output stabilization for central banks with a large time-inconsistency problem. Consequently, transparency is not necessarily welfare-enhancing. Beetsma and Jensen (2003) show that preference uncertainty is always detrimental. According to Hughes Hallett and Libich (2006) goal-transparency increases the central banks accountability for price stability, lowers inflation and increases credibility. Geraats (2007) argues that optimal transparency is characterized by a clear communication of the inflation target but an ambiguous communication of the output target and supply shocks. In this journal, Hahn (2009) analyzes the effects of transparency in a very general framework with correlation between the stochastic employment target and the stochastic relative weight of the policy targets. He finds that society favors opacity if its relative weight on inflation is sufficiently high.

As argued earlier, the existing literature sparely addresses the issues which this paper aims at. First, only few contributions explicitly analyze a possible divergence of the socially optimal transparency regimes and the preferences of a central bank. Hughes Hallett and Viegi (2003) show that the central bank may benefit from lower inflation through limited transparency of the relative importance of its policy targets. Society, however, would prefer transparency. Analyzing the transparency of voting behavior in central bank councils, Gersbach and Hahn (2008) show that transparency is detrimental and might create a conflict between socially desirable and individual optimal voting behavior. A conflict between practiced and socially desirable transparency regimes is also implicit in the analysis of ECB policy by Buiter (1999) and Svensson (2002). Buiter (1999) generally attacks the ECB because of its lack of transparency, openness and accountability; Svensson (2002) criticizes the ambiguous and asymmetric definition of price stability in the early years of the ECB. The optimal choice of goal-transparency is analyzed by Hughes Hallett and Libich (2006). They show that goal-transparency is socially beneficial since it reduces society's monitoring cost. Nevertheless, independent central bankers may not practice transparency to

avoid accountability.

Second, to our knowledge, there is no research which considers the link between the endogenous choices of delegation and transparency. Apart from transparency, the delegation solution is endogenously determined in many papers on central bank design. Eijffinger et al. (2000b), for example, analyze the optimal degree of conservatism in open economies. Hughes Hallett and Weymark (2004, 2005) or Lockwood et al. (1998) apply two-stage models of monetary policy with an endogenous choice of the institutional design in the first stage and policy implementation in the second stage. However, the interaction between the endogenous determination of the different features of central bank design has widely been neglected.

3 Theoretical framework

We apply a simple neoclassical model and keep it to a minimum complexity which suffices to derive the results. The applied game-theoretic framework stands in the tradition of the standard Barro and Gordon (1983) model with stochastic supply shocks. Aggregate supply is given by an expectations-augmented Phillips-curve

$$y = y^n + \pi - \pi^e + \epsilon, \tag{1}$$

where the (log of) output is determined by the (log of) natural rate of output y^n, the rate of inflation π which is assumed to be perfectly and directly controlled by the monetary authority, rationally formed inflation expectations of wage setters π^e and a stochastic supply shock ϵ (with $E[\epsilon] = 0$ and $Var[\epsilon] = \sigma_\epsilon^2$).

Social welfare is described by a standard quadratic loss function

$$L^s = \frac{1}{2}\alpha^M(\pi - \pi^*)^2 + \frac{1}{2}(y - y^*)^2, \tag{2}$$

where α^M denotes the relative weight the median voter assigns to deviations of inflation from its optimum π^* relative to deviations of output from $y^* > y^n$. The loss

function of the monetary authority differs from social loss in the target levels and the relative weight assigned to the goals:

$$l^m = \frac{1}{2}\alpha(\pi - \bar{\pi})^2 + \frac{1}{2}(y - \bar{y})^2. \tag{3}$$

with $\alpha = \chi\alpha^M$. The parameter $\chi \geq 0$ denotes the degree of effective conservatism[5] and $\bar{y} = y^* + \mu$ and $\bar{\pi} = \pi^* + v$ denote the stochastic policy targets of the monetary authority. Shocks to the target can be interpreted, e.g., as a changing committee composition of the decision-making body. Frequent changes in central banks' targets seem to be a relevant real world phenomenon. Fry et al. (2000) show that 39% of their sample countries substantially revise the inflation target more than annually. In our model, shocks are assumed to have zero mean as well as a constant and finite variance (σ_μ^2, σ_v^2), are uncorrelated ($E[v\mu] = 0$, $E[\epsilon\mu] = 0$, $E[\epsilon v] = 0$) and private information of the monetary authority.[6]

Monetary policy can be characterized by a two-stage process.[7] Stage 1 describes the determination of the institutional design of monetary policy. First, society chooses the delegation solution $0 \leq \chi < \infty$.[8] Second, the appointed central bank decides on the transparency regime. We distinguish 4 possible transparency strategies. Let $E[\bar{\pi}]$

[5] We do not rule out the case $\chi < 1$, i.e. a monetary authority that is less conservative than society.

[6] $E[\epsilon\mu] = 0$ and $E[\epsilon v] = 0$ seem plausible because the (non-autocorrelated) real shock hits the economy only after the target shocks has occured. Concerning the target shocks, it would rather seem plausible that, in the case of stochastic target weights, the targets shocks are correlated with the stochastic weights (Hahn, 2009). In our interpretation, it seems adequate to assume no systematic relation between the shocks; i.e., 'adjustments' of the inflation target are, on average, not accompanied by different output targets ($E[v\mu] = 0$).

[7] Hughes Hallet and Weymark (2004, 2005) and Lockwood et al. (1998) use a similar two-stage framework with an endogenous choice of the institutional design of a central bank.

[8] Note, that we do not analyze if delegation is beneficial. According to Rogoff (1985), delegating to an effectively conservative central bank enhances social welfare. However, information asymmetries, e.g. on policy targets, imply additional costs. This could in fact lead to higher social welfare under non-delegation. In the reminder of the paper, we focus on an analysis of monetary policy under delegation. Also, one could imagine that society strategically chooses the 'initial' targets of monetary policy. Mishkin and Schmidt-Hebel (2002) argue that there is a strong heterogeneity with respect to who chooses the targets in reality. Therefore, we do not explicitly model the choice of the targets and assume the 'initial' central bank targets to coincide with the socially optimal values.

and $E[\bar{y}]$ denote the information on the policy targets available to the public[9]

$$E[\bar{\pi}] = \pi^* + \tau_\pi v, \quad (4)$$

$$E[\bar{y}] = y^* + \tau_y \mu. \quad (5)$$

With $\tau_\pi = \tau_y = 1$ there is perfect transparency of both targets. With $\tau_\pi = \tau_y = 0$ the central bank discloses no information on the targets (perfect opacity). There are also two mixed regimes. With $\tau_\pi = 1$ (0) and $\tau_y = 0$ (1) there is transparency (opacity) of the inflation target but opacity (transparency) of the output target. We do not take into account noisy disclosure of information (see e.g. Morris and Shin, 2002 or Geraats, 2007); i.e., the central bank is able to perfectly signal the targets.[10]

In stage 2, the actual policy implementation process takes place. The sequential structure is as follows: First, the shocks to the policy targets occur and the monetary authority discloses information on the actual targets depending on the transparency solution as described above. Second, wage setters form inflation expectations without knowledge of the supply shock and given the information on the policy targets. Third, the shock ϵ occurs. Fourth, the monetary authority implements the rate of inflation minimizing its loss function.

The model is solved by backward induction. In a first step, equilibrium inflation and output is determined (stage-2-game), given the transparency regime (τ_π, τ_y) and the delegation solution (χ) chosen in stage 1. Then, the institutional arrangements resulting from the stage-1-game are identified using the expectations of the policy outcome in stage 2.

[9]Hence, we interpret transparency as disclosing information on the true target values leaving the distribution of shocks unchanged, see e.g. Hahn (2009).

[10]We can exclude strategies with $0 < \tau_\pi < 1$ and $0 < \tau_y < 1$. Besides simplifying the formal analysis it appears feasible since we analyze the case of an ex ante choice of the transparency regime. Similar to the Rogoff (1985) delegation solution, it is implicitly assumed that this institutional design is credible and not revised ex post. Hence, in this paper we do not analyze the incentives of central banks to deviate from this 'rule-based' transparency once the regime is established and the policy implementation process takes place.

4 Stage 2: Monetary policy implementation

Using backward induction the stage-2-game is solved. Minimizing the loss of the monetary authority (3) subject to the Phillips-curve (1) with respect to π and considering the private sectors' rational expectations yields equilibrium inflation and output:[11]

$$\pi^{\tau_\pi,\tau_y} = \pi^* + \frac{1}{\alpha}(y^* - y^n) - \frac{1}{1+\alpha}\epsilon + \frac{\alpha+\tau_\pi}{1+\alpha}\upsilon + \frac{1}{\alpha}\frac{\alpha+\tau_y}{1+\alpha}\mu, \tag{6}$$

$$y^{\tau_\pi,\tau_y} = y^n + \frac{\alpha}{1+\alpha}\epsilon + \frac{\alpha(1-\tau_\pi)}{1+\alpha}\upsilon + \frac{1-\tau_y}{1+\alpha}\mu. \tag{7}$$

Average inflation exceeds the optimal rate of inflation π^* by $\frac{1}{\alpha}(y^* - y^n)$ – reflecting the well-known inflationary bias. Average (log of) output equals the (log of) natural output. Different transparency regimes τ_π and τ_y do not have an impact on the average levels of inflation and output. However, transparency influences the variability of the macro variables and has opposite effects on inflation and output variability. Under transparency, expected inflation varies with the shocks μ and υ. Higher variability of inflation expectations then transmits to higher inflation variability:[12]

$$Var\left[\pi^{1,\tau_y}\right] = Var\left[\pi^{0,\tau_y}\right] + \frac{2\alpha+1}{(1+\alpha)^2}\sigma_\upsilon^2, \tag{8}$$

$$Var\left[\pi^{\tau_\pi,1}\right] = Var\left[\pi^{\tau_\pi,0}\right] + \frac{2\alpha+1}{\alpha^2(1+\alpha)^2}\sigma_\mu^2. \tag{9}$$

In contrast, transparency involves a stronger co-movement of inflation and private-sector inflation expectations because the information on target shocks is symmetric. According to (1), the resulting lower variability of the inflation expectations error under transparency leads to lower variation of output around its natural level:[13]

[11] See appendix A.1 for the derivation of the policy outcome. The results are similar to, e.g., Demertzis and Hughes Hallet (2007).

[12] See appendix A.2 for a comparison of variances.

[13] The expectations error is given by $\pi - \pi^e = \frac{\alpha(1-\tau_\pi)}{1+\alpha}\upsilon + \frac{1-\tau_y}{1+\alpha}\mu - \frac{1}{1+\alpha}\epsilon$. For transparency of both targets the error is independent of the period shocks to the targets and its variance is smaller compared to all other transparency regimes (τ_π, τ_y).

$$Var\left[y^{1,\tau_y}\right] = Var\left[y^{0,\tau_y}\right] - \frac{\alpha^2}{(1+\alpha)^2}\sigma_\epsilon^2. \tag{10}$$

$$Var\left[y^{\tau_\pi,1}\right] = Var\left[y^{\tau_\pi,0}\right] - \frac{1}{(1+\alpha)^2}\sigma_\mu^2. \tag{11}$$

5 Stage 1: Delegation solution and transparency regime

The analysis of the endogenous choice of the delegation solution (χ) and the transparency strategy (τ_π, τ_y) is based upon the ex ante expected losses of the monetary authority and society in stage 2. Due to the sequential interaction, we again derive the equilibrium strategies by backward induction. Given a delegation solution χ, the monetary authority determines its transparency strategy. Society decides on the delegation solution, anticipating the strategy of the monetary authority.

5.1 Choice of the transparency regime

The objective function of the monetary authority in stage 1 (ex ante expected loss) is derived by inserting (6) and (7) in (3) and applying the expectations operator (see Appendix B.1):

$$E[l^m(\tau_\pi, \tau_y)] = f + \frac{1}{2}\frac{\alpha(\tau_\pi - 1)^2}{1+\alpha}\sigma_\epsilon^2 + \frac{1}{2}\frac{(\alpha+\tau_y)^2}{\alpha(1+\alpha)}\sigma_\mu^2, \tag{12}$$

with $f = \frac{1}{2}\left(\frac{1+\alpha}{\alpha}\right)(y^* - y^n)^2 + \frac{1}{2}\frac{\alpha}{1+\alpha}\sigma_\epsilon^2$. Comparing expected losses for different transparency regimes reveals that the monetary authority always prefers transparency of the inflation target and opacity of the output target ($\tau_\pi = 1$ and $\tau_y = 0$). Even though the transparency of targets increases inflation variability and decreases output variability relative to opacity, both effects are beneficial for the central bank in the case of the inflation target. In contrast, both effects are detrimental in the case of the output target. In section 6 these effects are discussed in detail. Hence, independent

of the choice of χ by society the monetary authority decides on announcing the inflation target and on concealing the output target. The preferred order of transparency regimes is[14]

$$E[l^m(1,0)] < \{E[l^m(0,0)], E[l^m(1,1)]\} < E[l^m(0,1)]. \tag{13}$$

5.2 Choice of the delegation solution

The appointment of the monetary authority by society is based on the minimization of the expected social loss which is given by (see Appendix B.2)

$$\begin{aligned} E[l^s(\tau_\pi, \tau_y)] &= h + \frac{1}{2}\frac{\alpha^M(\alpha+\tau_\pi)^2 + \alpha^2(1-\tau_\pi)^2}{(1+\alpha)^2}\sigma_v^2 \\ &+ \frac{1}{2}\left(\frac{\frac{\alpha^M}{\alpha^2}(\alpha+\tau_y)^2 + (1-\tau_y)^2}{(1+\alpha)^2}\right)\sigma_\mu^2, \end{aligned} \tag{14}$$

with $h = \frac{1}{2}\left(\frac{\alpha^M}{\alpha^2}+1\right)(y^* - y^n)^2 + \frac{1}{2}\left(\frac{\alpha^M+\alpha^2}{(1+\alpha)^2}\right)\sigma_\epsilon^2$. As previously shown, the central bank practices transparency of the inflation target and opacity of the output target, independent of society's delegation solution. As a consequence, society minimizes the welfare loss $E[l^s(1,0)]$ by choosing the locally optimal delegation solution, given the monetary authority implements its preferred transparency strategy. Minimizing $E[l^s(1,0)]$ with respect to χ yields the equilibrium condition for the delegation solution

$$\frac{(y^* - y^n)^2}{\chi^3(\alpha^M)^2} + \frac{1+\alpha^M}{(1+\chi\alpha^M)^3}\sigma_\mu^2 = \frac{\alpha^M(\chi-1)}{(1+\chi\alpha^M)^3}\sigma_\epsilon^2. \tag{15}$$

In optimum, the marginal gain from higher effective conservatism which results from a lower inflationary bias and a lower effect of uncertainty of the output target on social welfare equals the marginal costs resulting from higher output variability. Equation (15) is only satisfied when the marginal cost term on the right is positive. This is only true for $\chi > 1$; i.e., society appoints a central bank which is more inflation averse than society.

[14] See Appendix C.1. The order between $E[l^m(0,0)]$ and $E[l^m(1,1)]$ depends on whether the degree of effective conservatism exceeds or falls short of $\chi = \frac{1}{\alpha^M}\frac{\sigma_\mu^2}{\sigma_v^2}\left(1+\sqrt{1+\frac{\sigma_v^2}{\sigma_\mu^2}}\right)$.

6 Discussion of the results

Under delegation, the equilibrium of the endogenously chosen delegation solution and transparency regime is characterized by an effectively conservative central bank ($\chi > 1$) as well as transparency of the inflation and opacity of the output target. In order to determine the welfare effects, the equilibrium has to be compared to the globally and socially optimal combination of effective conservatism and transparency, given that monetary policy is delegated. Using (14) and comparing the expected loss of society for different τ_π and τ_y reveals that society prefers either transparency or opacity of both targets:

$$argmin_{(\tau_\pi,\tau_y)^2} E[l^s(\tau_\pi,\tau_y)) = \begin{cases} (1,1) & \text{if } \chi > \hat{\chi} \\ (0,0) & \text{if } \chi < \hat{\chi} \end{cases}, \tag{16}$$

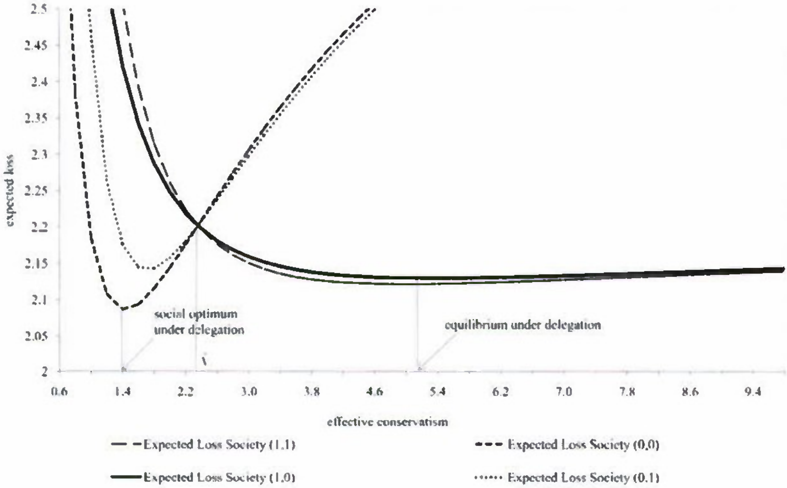
with $\hat{\chi} = 1 + \sqrt{1 + \frac{1}{\alpha^M}}$.[15] Hence, under delegation, the globally optimal solution for society is characterized by a delegation solution which is accompanied by either transparency or opacity of both targets. Consequently, the equilibrium strategy does not represent the social optimum under delegation.

Figure 2 exemplarily displays the ex ante expected social loss for each possible transparency regime (τ_π, τ_y). The figure represents the case where the social optimum under delegation is characterized by opacity of both targets ($\tau_\pi = 0, \tau_y = 0$).[16] For degrees of effective conservatism below $\hat{\chi}$ society prefers total opacity. Beyond $\hat{\chi}$ total transparency yields lower expected social losses. The transparency strategy practiced by the monetary authority ($\tau_\pi = 1, \tau_y = 0$) is outperformed either by total transparency ($\chi > \hat{\chi}$) or total opacity ($\chi < \hat{\chi}$). The loss in the equilibrium combination of delegation and transparency – the minimum of the continuous black line – is larger than in the social optimum under delegation.

[15] See Appendix C.2.

[16] The figure is based on simulations of the above model for the parameters values: $y^* - y^n = \sigma_\varepsilon^2 = 1$, $\sigma_\nu^2 = 1.5$ and $\sigma_\mu^2 = 2$ and $\alpha^M = 1.2$.

Figure 2: Opacity of both targets as social optimum



So far, we have shown that there is a conflict between the preferred transparency regimes of society and the central bank.[17] In the following, we analyze in more detail, how and why the preferred regimes differ. As shown above, transparency of the inflation target decreases output variability relative to opacity. This effect is beneficial for both, the central bank and society. Under transparency; i.e., symmetric information, shocks to the inflation target do not cause inflation expectation errors and, thus, do not alter output (variability). The output targets of the central bank ($\bar{y}$) and society (y^*) are independent of inflation target shocks. As a consequence, lower output variability results in lower expected loss and transparency is beneficial. In contrast, even though a transparent inflation target unequivocally increases inflation

[17] All qualitative results in this paper are not sensitive to changing the structural parameters of the model, e.g. a different slope of the Phillips-curve which is normalized to 1 in our model.

variability, this effect is detrimental for society but beneficial for the central bank. For the latter, an inflation target shock under transparency pushes actual and targeted inflation in the same direction and to the same extent (see (6) for $\tau_\pi = 1$). As a result, the deviation from the target is not affected by the shocks. Higher inflation variations under transparency, thus, are accompanied by lower variations in deviations from the target than under opacity. Expected central bank loss is lower. However, society's expected loss increases because a target shock alters inflation but leaves the social target π^* unchanged. The resulting higher variability of target deviations yields higher expected social loss.

With regard to output target shocks, the inflation variability effect of transparency is detrimental for the central bank and society. Shocks to the output target leave the inflation targets ($\bar{\pi}$ and π^*) unaffected but lead to higher inflation variability under transparency (see (6) for $\tau_\pi = 1$). Hence, inflation fluctuations around the target are more pronounced, implying higher expected loss. The output variability effect is now beneficial for society but detrimental for the central bank. Revealing the output target yields inflation expectations errors which are not sensitive to target shocks. Under transparency, output is, thus, independent of the shocks. For the central bank, shocks induce fluctuations of the central bank's output target which leads to higher variation in target deviations and higher expected loss. Society's output target remains unaffected under transparency. Thus, target deviations vary less, implying lower expected social costs. As a result of all effects, the central bank always benefits from transparency of the inflation target and opacity of the output target. In contrast, society always faces a trade-off.[18]

The conflict between the socially optimal and the chosen transparency regime can

[18]Note, that society's trade-off between transparency and opacity is identical for both targets. In other words, $\hat{\chi}$ is the threshold level of effective conservatism which exactly cancels out the inflation and output variability effects for both, the inflation target and the output target shocks (see appendix C.2).

be triggered by two differences in the objective functions of society and the central bank. First, under delegation, the central banks' targets are subject to shocks. Second, the central bank's relative weight on the targets differs from the preferences of society. In order to separate the effect, we analyze the case $\alpha = \alpha^M$; i.e., the central bank and society attach the same relative weights to the targets ($\chi = 1$) but the central bank has private information. Because society's threshold level for transparency is always greater than 1 ($\tilde{\chi} = 1 + \sqrt{1 + 1/\alpha^M}$), opacity will be socially superior in this case. Only $\alpha > \alpha^M$ limits the social costs of transparency and a transparent regime may become desirable. Making the central bank more inflation averse increases its costs of inflation variance relative to output variance. This in fact alters society's trade-off with respect to transparency. As evident from equations (8) to (11), a higher relative target weight α mitigates the detrimental inflation variability effects. In contrast, the beneficial output variability effects are more pronounced.

The above findings have some interesting implications. One policy implication of the model might be that, due to the strong conflict between the preferred strategies by society and the central bank, the choice of the transparency regime should be part of the delegation solution of society. This solution would solve the conflict but it would require credibility of such an arrangement; i.e., central banks do not deviate from such a regime in the policy implementation process.

Another prediction of the model is that central banks always choose to publish inflation targets and conceal output targets. Traditionally, central banks did not publish inflation targets which is at odds with the models prediction. However, especially in times of more independent central banks, transparency has become a necessary condition for the accountability and the credibility of central banks. Many central banks have increased transparency in the recent past (Blinder et al., 2008). Today, many central banks publish inflation targets rather than output targets (Geraats, 2006). A prominent example is the ECB which has a transparent inflation target of below, but

close to 2%. There is, however, hardly any information on the output target. The analysis of Fry et al. (2000) reveals that 59% of the central banks in their sample publish explicit inflation targets.

Many central banks have often been accused of being too secretive. A prominent example is the ECB (Buiter, 1999; Svensson, 2002). However, our model implies that a central bank can also be too transparent. In the case of total secrecy minimizing social costs, the predicted central bank behavior; i.e., the publication of inflation targets, is socially sub-optimal.

In our model, inflation and output variability effects are the only determinants of the desirability of transparency. Of course, we do not claim that our model captures all motives for transparency. The literature discusses a variety of different motives. Milton Friedman suggested 'that by far and away the two most important variables in their loss function are avoiding accountability on the one hand and achieving public prestige on the other' (quoted from Fischer, 1990, p. 1181). Avoiding accountability may imply that central banks choose to be opaque. Applying the theory of bureaucracy to the ECB, Forder (2002) argues that central banks pursue their own goals as maintaining independence, prestige, maximum discretion and avoiding blame for failure. This may lead the ECB to ambiguous communication and intransparency. Dincer and Eichengreen (2009) also argue that transparency can go too far and central banks might be subject to pressure from different interest groups and their independence might be challenged. Contrarily, a Niskanen type of argument of budget maximizing would imply that central banks tend to maximize transparency. Through the preparation of reports and the excessive communication with the public central bankers may try to maximize the size of their institution.[19]

[19]See Berger et al. (2006), p. 6 in the context of central bank independence.

7 Conclusion

In this paper, we applied a simple neoclassical time-inconsistency framework in which monetary policy is modeled as a two-stage game between the private sector and the central bank. In the first stage, society first chooses the delegation solution (effective conservatism) and the appointed central bank then determines the transparency regime. In the second stage, monetary policy is conducted. We show that, in a model with stochastic policy targets and asymmetric information, the transparency regime chosen by the monetary authority, which the model predicts to be more inflation averse than society, does not coincide with the regime preferred by society. Independent of society's choice of the degree of effective conservatism, the central bank practices transparency of the inflation and opacity of the output target. However, society either prefers transparency or opacity of both targets. The results imply that there is a strong conflict between socially optimal and practiced transparency regimes. As a conclusion, the choice of the transparency regime should be part of the optimal delegation solution.

While many central banks have often been accused of being too secretive our results imply that central banks can also be excessively transparent. Furthermore, the model's prediction with respect to the publication of targets is in line with the observed behavior of many central banks. In practice, most central banks seem to have transparent inflation targets but conceal other targets (Geraats, 2006).

Appendix A: Derivation of equilibrium monetary policy outcome

Appendix A.1: Derivation of equilibrium inflation and output

Inserting aggregate supply (1) in the loss of the monetary authority (3) and differentiating with respect to inflation yields the first-order condition

$$\alpha(\pi - \bar{\pi}) + y^n - \bar{y} + \pi - \pi^e + \epsilon = 0. \tag{A.1}$$

$$(1+\alpha)\pi = \alpha\bar{\pi} + \bar{y} - y^n + \pi^e - \epsilon. \tag{A.2}$$

The private sector forms rational inflation expectations (i.e. $E[\pi] = \pi^e$), given the information on the policy targets (4) and (5). Inflation expectations can be calculated as follows.

$$(1+\alpha)E[\pi] = \alpha E[\bar{\pi}] + E[\bar{y}] - y^n + E[\pi^e] - E[\epsilon], \tag{A.3}$$

$$(1+\alpha)\pi^e = \alpha\pi^* + \alpha\tau_\pi\upsilon + y^* + \tau_y\mu - y^n + \pi^e, \tag{A.4}$$

$$\pi^e = \pi^* + \frac{1}{\alpha}(y^* - y^n) + \tau_\pi\upsilon + \frac{1}{\alpha}\tau_y\mu. \tag{A.5}$$

Inserting inflation expectations in (A.2) and using $\bar{\pi} = \pi^* + \upsilon$ and $\bar{y} = y^* + \mu$ yields inflation in equilibrium:

$$(1+\alpha)\pi = \alpha\bar{\pi} + \bar{y} - y^n + \pi^* + \frac{1}{\alpha}(y^* - y^n) + \tau_\pi\upsilon + \frac{1}{\alpha}\tau_y\mu - \epsilon, \tag{A.6}$$

$$(1+\alpha)\pi = \alpha(\pi^* + \upsilon) + y^* + \mu - y^n + \pi^* + \frac{1}{\alpha}(y^* - y^n) + \tau_\pi\upsilon + \frac{1}{\alpha}\tau_y\mu - \epsilon, \tag{A.7}$$

$$\pi^{\tau_\pi,\tau_y} = \pi^* + \frac{1}{\alpha}(y^* - y^n) - \frac{1}{1+\alpha}\epsilon + \frac{\alpha+\tau_\pi}{1+\alpha}\upsilon + \frac{1}{\alpha}\frac{\alpha+\tau_y}{1+\alpha}\mu. \tag{A.8}$$

Calculating unexpected inflation and inserting in the Phillips-curve (1) yields equilibrium output:

$$\pi - \pi^e = -\frac{1}{1+\alpha}\epsilon + \frac{\alpha+\tau_\pi}{1+\alpha}\upsilon + \frac{1}{\alpha}\frac{\alpha+\tau_y}{1+\alpha}\mu - \tau_\pi\upsilon - \frac{1}{\alpha}\tau_y\mu, \tag{A.9}$$

$$\pi - \pi^e = -\frac{1}{1+\alpha}\epsilon + \frac{\alpha(1-\tau_\pi)}{1+\alpha}\upsilon + \frac{1-\tau_y}{1+\alpha}\mu, \tag{A.10}$$

$$y = y^n + \pi - \pi^e + \epsilon = y^n + \frac{\alpha(1-\tau_\pi)}{1+\alpha}\upsilon + \frac{1-\tau_y}{1+\alpha}\mu - \frac{1}{1+\alpha}\epsilon + \epsilon, \tag{A.11}$$

$$y^{\tau_\pi,\tau_y} = y^n + \frac{\alpha}{1+\alpha}\epsilon + \frac{\alpha(1-\tau_\pi)}{1+\alpha}\upsilon + \frac{1-\tau_y}{1+\alpha}\mu. \tag{A.12}$$

Appendix A.2: Variance of inflation and output under different transparency regimes

Under the assumption of uncorrelated shocks; i.e., zero covariance, the variance of equilibrium inflation (see (6)) is given by

$$Var\left[\pi^{\tau_\pi,\tau_y}\right] = Var\left[\pi^* + \frac{1}{\alpha}(y^* - y^n) - \frac{1}{1+\alpha}\epsilon + \frac{\alpha+\tau_\pi}{1+\alpha}\upsilon + \frac{1}{\alpha}\frac{\alpha+\tau_y}{1+\alpha}\mu\right], \tag{A.13}$$

$$Var\left[\pi^{\tau_\pi,\tau_y}\right] = \frac{1}{(1+\alpha)^2}\sigma_\epsilon^2 + \frac{(\alpha+\tau_\pi)^2}{(1+\alpha)^2}\sigma_\upsilon^2 + \frac{1}{\alpha^2}\frac{(\alpha+\tau_y)^2}{(1+\alpha)^2}\sigma_\mu^2. \tag{A.14}$$

Now, the difference in inflation variance between a transparent and an opaque inflation target can be calculated as

$$\begin{aligned} Var\left[\pi^{1,\tau_y}\right] - Var\left[\pi^{0,\tau_y}\right] &= \left(\frac{1}{(1+\alpha)^2}\sigma_\epsilon^2 + \frac{(\alpha+1)^2}{(1+\alpha)^2}\sigma_\upsilon^2 + \frac{1}{\alpha^2}\frac{(\alpha+\tau_y)^2}{(1+\alpha)^2}\sigma_\mu^2\right) \\ &\quad - \left(\frac{1}{(1+\alpha)^2}\sigma_\epsilon^2 + \frac{\alpha^2}{(1+\alpha)^2}\sigma_\upsilon^2 + \frac{1}{\alpha^2}\frac{(\alpha+\tau_y)^2}{(1+\alpha)^2}\sigma_\mu^2\right) \\ &= \frac{2\alpha+1}{(1+\alpha)^2}\sigma_\upsilon^2 > 0. \end{aligned} \tag{A.15}$$

Similarily, the difference in inflation variance between a transparent and an opaque output target is given by

$$\begin{aligned} Var\left[\pi^{\tau_\pi,1}\right] - Var\left[\pi^{\tau_\pi,0}\right] &= \left(\frac{1}{(1+\alpha)^2}\sigma_\epsilon^2 + \frac{(\alpha+\tau_\pi)^2}{(1+\alpha)^2}\sigma_\upsilon^2 + \frac{1}{\alpha^2}\frac{(\alpha+1)^2}{(1+\alpha)^2}\sigma_\mu^2\right) \\ &\quad - \left(\frac{1}{(1+\alpha)^2}\sigma_\epsilon^2 + \frac{(\alpha+\tau_\pi)^2}{(1+\alpha)^2}\sigma_\upsilon^2 + \frac{1}{\alpha^2}\frac{\alpha^2}{(1+\alpha)^2}\sigma_\mu^2\right) \\ &= \frac{1}{\alpha^2}\frac{2\alpha+1}{(1+\alpha)^2}\sigma_\mu^2 > 0. \end{aligned} \tag{A.16}$$

The variance of output is

$$Var\left[y^{\tau_\pi,\tau_y}\right] = Var\left[y^n + \frac{\alpha}{1+\alpha}\epsilon + \frac{\alpha(1-\tau_\pi)}{1+\alpha}\upsilon + \frac{1-\tau_y}{1+\alpha}\mu\right], \tag{A.17}$$

$$Var\left[y^{\tau_\pi,\tau_y}\right] = \frac{\alpha^2}{(1+\alpha)^2}\sigma_\epsilon^2 + \frac{\alpha^2(1-\tau_\pi)^2}{(1+\alpha)^2}\sigma_\upsilon^2 + \frac{(1-\tau_y)^2}{(1+\alpha)^2}\sigma_\mu^2. \qquad (A.18)$$

Output variability differs between a transparent and an opaque inflation target according to

$$\begin{aligned} Var\left[y^{1,\tau_y}\right] - Var\left[y^{0,\tau_y}\right] &= \left(\frac{\alpha^2}{(1+\alpha)^2}\sigma_\epsilon^2 + \frac{(1-\tau_y)^2}{(1+\alpha)^2}\sigma_\mu^2\right) \qquad (A.19) \\ &\quad -\left(\frac{\alpha^2}{(1+\alpha)^2}\sigma_\epsilon^2 + \frac{\alpha^2}{(1+\alpha)^2}\sigma_\upsilon^2 + \frac{(1-\tau_y)^2}{(1+\alpha)^2}\sigma_\mu^2\right) \\ &= -\frac{\alpha^2}{(1+\alpha)^2}\sigma_\upsilon^2 < 0 \end{aligned}$$

and between a transparent and an opaque output target according to

$$\begin{aligned} Var\left[y^{\tau_\pi,1}\right] - Var\left[y^{\tau_\pi,0}\right] &= \left(\frac{\alpha^2}{(1+\alpha)^2}\sigma_\epsilon^2 + \frac{\alpha^2(1-\tau_\pi)^2}{(1+\alpha)^2}\sigma_\upsilon^2\right) \qquad (A.20) \\ &\quad -\left(\frac{\alpha^2}{(1+\alpha)^2}\sigma_\epsilon^2 + \frac{\alpha^2(1-\tau_\pi)^2}{(1+\alpha)^2}\sigma_\upsilon^2 + \frac{1}{(1+\alpha)^2}\sigma_\mu^2\right) \\ &= -\frac{1}{(1+\alpha)^2}\sigma_\mu^2 < 0. \end{aligned}$$

Appendix B: Derivation of ex ante expected loss

Appendix B.1: Derivation of the ex ante expected loss of the monetary authority

First, the period loss is obtained by inserting equilibrium inflation (6) and output (7) from stage 2 in the loss function of the monetary authority (3):

$$\begin{aligned} l^m(\tau_\pi,\tau_y) &= \frac{1}{2}\alpha\left(\pi^* + \frac{1}{\alpha}(y^* - y^n) - \frac{1}{1+\alpha}\epsilon + \frac{\alpha+\tau_\pi}{1+\alpha}\upsilon + \frac{1}{\alpha}\frac{\alpha+\tau_y}{1+\alpha}\mu - \bar{\pi}\right)^2 \\ &\quad + \frac{1}{2}\left(y^n + \frac{\alpha}{1+\alpha}\epsilon + \frac{\alpha(1-\tau_\pi)}{1+\alpha}\upsilon + \frac{1-\tau_y}{1+\alpha}\mu - \bar{y}\right)^2. \qquad (B.1) \end{aligned}$$

Using $\bar{y} = y^* + \mu$ and $\bar{\pi} = \pi^* + \upsilon$, rewriting and applying the expectations operator yields

$$\begin{aligned} E\left[l^m(\tau_\pi,\tau_y)\right] &= \frac{1}{2}\alpha E\left[\left(\frac{1}{\alpha}(y^* - y^n) - \frac{1}{1+\alpha}\epsilon - \frac{1-\tau_\pi}{1+\alpha}\upsilon + \frac{1}{\alpha}\frac{\alpha+\tau_y}{1+\alpha}\mu\right)^2\right] \\ &\quad + \frac{1}{2}E\left[\left(y^n - y^* + \frac{\alpha}{1+\alpha}\epsilon + \frac{\alpha(1-\tau_\pi)}{1+\alpha}\upsilon - \frac{(\alpha+\tau_y)}{1+\alpha}\mu\right)^2\right]. \end{aligned}$$

Under the assumption that shocks have a mean of zero and are uncorrelated ($E[v\mu] = 0$, $E[\epsilon\mu] = 0$, $E[\epsilon v] = 0$) we obtain equation (12):

$$
\begin{aligned}
E\left[l^m(\tau_\pi, \tau_y)\right] &= \frac{1}{2}\frac{1}{\alpha}(y^* - y^n)^2 + \frac{1}{2}\frac{\alpha}{(1+\alpha)^2}E[\epsilon^2] + \frac{1}{2}\frac{\alpha(1-\tau_\pi)^2}{(1+\alpha)^2}E[v^2] \\
&+ \frac{1}{2}\frac{1}{\alpha}\frac{(\alpha+\tau_y)^2}{(1+\alpha)^2}E[\mu^2] + \frac{1}{2}(y^* - y^n)^2 + \frac{1}{2}\frac{\alpha^2}{(1+\alpha)^2}E[\epsilon^2] \\
&+ \frac{1}{2}\frac{\alpha^2(1-\tau_\pi)^2}{(1+\alpha)^2}E[v^2] + \frac{1}{2}\frac{(\alpha+\tau_y)^2}{(1+\alpha)^2}E[\mu^2].
\end{aligned}
$$

$$
\begin{aligned}
E[l^m(\tau_\pi, \tau_y)] &= \frac{1}{2}\left(\frac{1+\alpha}{\alpha}\right)(y^* - y^n)^2 + \frac{1}{2}\frac{\alpha}{1+\alpha}\sigma_\epsilon^2 \\
&+ \frac{1}{2}\frac{\alpha(\tau_\pi - 1)^2}{1+\alpha}\sigma_v^2 + \frac{1}{2}\frac{(\alpha+\tau_y)^2}{\alpha(1+\alpha)}\sigma_\mu^2. \qquad \text{(B.2)}
\end{aligned}
$$

Appendix B.2: Derivation of the ex ante expected social loss

Inserting equilibrium inflation (6) and output (7) from stage 2 in the social loss function (2) yields

$$
\begin{aligned}
l^s(\tau_\pi, \tau_y) &= \frac{1}{2}\alpha^M\left(\frac{1}{\alpha}(y^* - y^n) - \frac{1}{1+\alpha}\epsilon + \frac{\alpha+\tau_\pi}{1+\alpha}v + \frac{1}{\alpha}\frac{\alpha+\tau_y}{1+\alpha}\mu\right)^2 \\
&+ \frac{1}{2}\left(y^n - y^* + \frac{\alpha}{1+\alpha}\epsilon + \frac{\alpha(1-\tau_\pi)}{1+\alpha}v + \frac{1-\tau_y}{1+\alpha}\mu\right)^2. \qquad \text{(B.3)}
\end{aligned}
$$

Applying the expectations operator and taking into account that the zero-mean shocks are uncorrelated we obtain equation (14):

$$
\begin{aligned}
E[l^s(\tau_\pi, \tau_y)] &= \frac{1}{2}\alpha^M E\left[\left(\frac{1}{\alpha}(y^* - y^n) - \frac{1}{1+\alpha}\epsilon + \frac{\alpha+\tau_\pi}{1+\alpha}v + \frac{1}{\alpha}\frac{\alpha+\tau_y}{1+\alpha}\mu\right)^2\right] \\
&+ \frac{1}{2}E\left[\left(y^n - y^* + \frac{\alpha}{1+\alpha}\epsilon + \frac{\alpha(1-\tau_\pi)}{1+\alpha}v + \frac{1-\tau_y}{1+\alpha}\mu\right)^2\right]. \qquad \text{(B.4)}
\end{aligned}
$$

$$
\begin{aligned}
E[l^{s}(\tau_\pi,\tau_y)] &= \frac{1}{2}\frac{\alpha^M}{\alpha^2}(y^* - y^n)^2 + \frac{1}{2}\frac{\alpha^M}{(1+\alpha)^2}E[\epsilon^2] + \frac{1}{2}\frac{\alpha^M(\alpha+\tau_\pi)^2}{(1+\alpha)^2}E[v^2] + \\
&\quad \frac{1}{2}\frac{\alpha^M}{\alpha^2}\frac{(\alpha+\tau_y)^2}{(1+\alpha)^2}E[\mu^2] + \frac{1}{2}(y^n - y^*)^2 + \frac{1}{2}\frac{\alpha^2}{(1+\alpha)^2}E[\epsilon^2] \\
&\quad + \frac{1}{2}\frac{\alpha^2(1-\tau_\pi)^2}{(1+\alpha)^2}E[v^2] + \frac{1}{2}\frac{(1-\tau_y)^2}{(1+\alpha)^2}E[\mu^2].
\end{aligned}
$$

$$
\begin{aligned}
E[l^{s}(\tau_\pi,\tau_y)] &= \frac{1}{2}\left(\frac{\alpha^M}{\alpha^2}+1\right)(y^* - y^n)^2 + \frac{1}{2}\left(\frac{\alpha^M+\alpha^2}{(1+\alpha)^2}\right)\sigma_\epsilon^2 \\
&\quad + \frac{1}{2}\frac{\alpha^M(\alpha+\tau_\pi)^2 + \alpha^2(1-\tau_\pi)^2}{(1+\alpha)^2}\sigma_v^2 \\
&\quad + \frac{1}{2}\left(\frac{\frac{\alpha^M}{\alpha^2}(\alpha+\tau_y)^2 + (1-\tau_y)^2}{(1+\alpha)^2}\right)\sigma_\mu^2. \qquad \text{(B.5)}
\end{aligned}
$$

Appendix C: Preferred transparency regimes

Appendix C.1: Preferred transparency regime of the monetary authority

The ex ante expected losses of the monetary authority [see equation (12)] for different transparency regimes (τ_π, τ_y) are given by

$$
\begin{aligned}
E[l^m(1,1)] &= f + \frac{1}{2}\frac{1+\alpha}{\alpha}\sigma_\mu^2, & \text{(C.1)}\\
E[l^m(1,0)] &= f + \frac{1}{2}\frac{\alpha}{1+\alpha}\sigma_\mu^2, & \text{(C.2)}\\
E[l^m(0,1)] &= f + \frac{1}{2}\frac{\alpha}{1+\alpha}\sigma_v^2 + \frac{1}{2}\frac{1+\alpha}{\alpha}\sigma_\mu^2, & \text{(C.3)}\\
E[l^m(0,0)] &= f + \frac{1}{2}\frac{\alpha}{1+\alpha}\sigma_v^2 + \frac{\alpha}{1+\alpha}\sigma_\mu^2. & \text{(C.4)}
\end{aligned}
$$

Since $\frac{\alpha}{1+\alpha}\sigma_\mu^2 < \frac{1+\alpha}{\alpha}\sigma_\mu^2$ and $\frac{\alpha}{1+\alpha}\sigma_v^2 > 0$, equation (13) holds and the monetary authority strictly prefers transparency of the inflation target and opacity of the output target

– independent of the delegation solution:

$$E[l^m(1,0)] < \{E[l^m(0,0)], E[l^m(1,1)]\} < E[l^m(0,1)]. \tag{C.5}$$

Appendix C.2 Preferred transparency regime of society

The ex ante expected social losses [see equation (14)] for different transparency regimes (τ_π, τ_y) are given by

$$E[l^s(1,1)] = h + \frac{1}{2}\alpha^M\sigma_v^2 + \frac{1}{2}\frac{\alpha^M}{\alpha^2}\sigma_\mu^2, \tag{C.6}$$

$$E[l^s(1,0)] = h + \frac{1}{2}\alpha^M\sigma_v^2 + \frac{1}{2}\frac{(1+\alpha^M)}{(1+\alpha)^2}\sigma_\mu^2, \tag{C.7}$$

$$E[l^s(0,1)] = h + \frac{1}{2}\frac{\alpha^2(1+\alpha^M)}{(1+\alpha)^2}\sigma_v^2 + \frac{1}{2}\frac{\alpha^M}{\alpha^2}\sigma_\mu^2, \tag{C.8}$$

$$E[l^s(0,0)] = h + \frac{1}{2}\frac{\alpha^2(1+\alpha^M)}{(1+\alpha)^2}\sigma_v^2 + \frac{1}{2}\frac{(1+\alpha^M)}{(1+\alpha)^2}\sigma_\mu^2. \tag{C.9}$$

Comparison:

1. $E[l^s(1,1)] < E[l^s(1,0)]$ if

$$\frac{\alpha^M}{\alpha^2} < \frac{(1+\alpha^M)}{(1+\alpha)^2} \tag{C.10}$$

   with $\alpha = \chi\alpha^M$. Solving for χ yields

$$\chi > \tilde{\chi} = \sqrt{1+\frac{1}{\alpha^M}}. \tag{C.11}$$

2. $E[l^s(1,1)] < E[l^s(0,1)]$ if

$$\alpha^M < \frac{(1+\alpha^M)\alpha^2}{(1+\alpha)^2} \Rightarrow \frac{\alpha^M}{\alpha^2} < \frac{(1+\alpha^M)}{(1+\alpha)^2}. \tag{C.12}$$

   The above condition equals condition (C.10). Consequently:

$$\chi > \tilde{\chi} = \sqrt{1+\frac{1}{\alpha^M}}. \tag{C.13}$$

3. $E[l^s(1,1)] < E[l^s(0,0)]$ if

$$\alpha^M \sigma_v^2 + \frac{\alpha^M}{\alpha^2}\sigma_\mu^2 < \frac{\alpha^2(1+\alpha^M)}{(1+\alpha)^2}\sigma_v^2 + \frac{(1+\alpha^M)}{(1+\alpha)^2}\sigma_\mu^2. \tag{C.14}$$

$$\left(\underbrace{\alpha^M - \frac{(1+\alpha^M)\alpha^2}{(1+\alpha)^2}}_{A}\right)\sigma_v^2 < \left(\underbrace{\frac{(1+\alpha^M)}{(1+\alpha)^2} - \frac{\alpha^M}{\alpha^2}}_{-A\frac{1}{\alpha^2}}\right)\sigma_\mu^2. \tag{C.15}$$

Since $\sigma_\mu^2, \sigma_v^2 > 0$ condition (C.15) is only satisfied if $A < 0$:

$$\alpha^M - \frac{(1+\alpha^M)\alpha^2}{(1+\alpha)^2} < 0. \tag{C.16}$$

The above condition equals condition (C.12). Consequently:

$$\chi > \hat{\chi} = \sqrt{1 + \frac{1}{\alpha^M}}. \tag{C.17}$$

4. $E[l^s(0,0)] < E[l^s(1,0)]$ if

$$\alpha^M > \frac{(1+\alpha^M)\alpha^2}{(1+\alpha)^2}. \tag{C.18}$$

The above condition is inverse to condition (C.12). Consequently:

$$\chi < \hat{\chi} = \sqrt{1 + \frac{1}{\alpha^M}}. \tag{C.19}$$

5. $E[l^s(0,0)] < E[l^s(0,1)]$ if

$$\frac{\alpha^M}{\alpha^2} > \frac{(1+\alpha^M)}{(1+\alpha)^2}. \tag{C.20}$$

The above condition is inverse to condition (C.10). Consequently:

$$\chi < \hat{\chi} = \sqrt{1 + \frac{1}{\alpha^M}}. \tag{C.21}$$

The above conditions determine the ordering of transparency strategies with respect to social welfare as shown in equation (16).

$$argmin_{(\tau_x,\tau_y)^2} E[l^s(\tau_x,\tau_y)) = \begin{cases} (1,1) & \text{if } \chi > \hat{\chi} \\ (0,0) & \text{if } \chi < \hat{\chi} \end{cases}. \tag{C.22}$$

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